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A Survey of American Honeys

2. Characterization of Individual Floral Types of Honey 1/

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Number two in a series of ten articles on the different honeys of America.

AS A RESULT of our comprehensive analytical survey of honeys from the United States, we have complete data on 504 samples of honey and honeydew from 47 of the 50 States. These are from 83 floral types and 93 blends of known composition, as well as other blends characterized by area of production and time of harvest. By examination of the values found for the individual samples, we have obtained information on how the many different kinds of honey compare with each other.

It is well known that various honeys have certain characteristics - tupelo and sage honey are non-granulating, tulip tree honey is dark, cotton honey granulates quickly, and so on. In the table are shown the characteristics of 74 floral types of honey and 4 honeydew types, compared with the average composition of honey, which was given in the first article in this series. In this table a plus sign means that the honey is higher than the average in that particular characteristic. A minus sign means that it is lower than the average. If no mark is given, the honey is near the average for that particular characteristic. In the case of diastase, an "n" means that not enough data were available to give an estimate. We have not included moisture content in this table because we do not feel that it is a characteristic of the floral type of honey, but rather depends on other factors. No honey type was listed as minus for granulating tendency unless it was substantially non-granulating in our test. Those marked plus are particularly prone to granulate. Honeys not marked are average in granulating tendency under the conditions we used —in six months storage after heating to liquefy, they would deposit thin layers (to ¼") or clumps of crystals in a jar.

Where a plus is marked for pH it indicates a honey type showing less active acidity than the average. As an example of reading the table, alfalfa honey granulates more, is higher in dextrose, sucrose and lactone/free acid ratio than the average honey. It is lower than the average honey in its content of higher sugars, undetermined material, ash, and nitrogen. It is near the average values in all of the other characteristics.

For the more important and more common honey types, this table uses the average of many samples. For many of the other more unusual or locally-produced floral sources, there may have been only one or two samples analyzed.

This table provides a quick way to compare many of the more important honey types one with another and to find floral types of honey with the desired physical and chemical characteristics for any particular purpose.

1/ This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

TABLE 1. Characterization of Various Floral Types of Honey

	Color	Granulation	Levulose	Dextrose	Sucrose	Maltose	Higher Sugars	Undetermined	pH	Free Acidity	Lactone	Total Acidity	Lactone/Free Acid	Ash	Nitrogen	Diastase
Alfalfa		+		+	+		-	-					+	-	-	
Aster	+	-			-	+			+		-		-	+		n[1]
Athel Tree	+	+	+	+			-							+	+	n
Bamboo, Japanese			-			+										n
Basswood														-	-	
Bergamot	+		+								+	+				n
Blackberry	+	-		-		+	+		+				-	+		-
Blueberry	+					+			+							n
Blue Curls		+	-	+					-		+					n
Bluevine			-	-												n
Boneset	+		+	-								+			+	
Buckwheat	+		-		+					+		+				+
Canteloupe		+		+							+	+			-	-
Cape vine			-				-								-	
Chinquapin	+	-	-	-		+	+	+	+		-		-			
Clover, crimson	-								-					-	-	
Clover, hubam	-			+			-							-	-	n
Clover, sweet yellow	-		+		+					-		-	+	-	-	n
Coralvine	+	-	-	-			+	+	+	+		+		+	+	n
Cotton		+		+		-	-		+					+		
Cranberry	+	-	-	-			+	+	+					+		
Galiberry		-	+						+						-	
Goldenrod				+	-		-		+		-		-			+
Grape	+	-	-	-		+						+			+	n
Holly	+	-		-		+	+		+							n
Horsemint				+			-		-		+	+	+			
Locust		-	+	-						-		-		-	-	-
Manzanita		+	-	+						-		-			-	n
Marigold				+			-		-		+		+	-		+
Mesquite		+	+	+			-				-				-	n

Table 1 (cont.)

	Color	Granulation	Levulose	Dextrose	Sucrose	Maltose	Higher Sugars	Undetermined	pH	Free Acidity	Lactone	Total Acidity	Lactone/Free Acid	Ash	Nitrogen	Diastase
Mexican clover	+	-								+		+				+
Mint	-			+	+			-							-	
Mountain laurel	-	-	-	-	-	+	+	+	+	-	-	-	-			+
Mustard	+	-		-		+			+					+	+	
Orange									-		+		+	-		n
Orange-grapefruit					+									-	-	-
Palmetto		-				+			+	-		-			-	-
Palmetto, saw	+										+	+	+	+	-	-
Pepperbush	+		-					+			+			+		-
Peppermint	+		+						+				-	+		n
Peppervine	+	-	-	-		+									-	-
Poison oak		-		-		+	+	+						+	+	n
Privet	+						-		-	+	+	+				n
Prune	+	+	-	-		+	-		+	-	-	-	-	+	+	n
Raspberry	+	-	-	-			+					+		+	+	-
Rhododendron	-	-	-	-		+		+	+	-	-	-			-	+
Sage		-	+	-												n
Snowbrush	+									+		+				+
Sourwood		-		-		+	+		+		-	-			-	
Spanish needle	+	-	+	-							+	+	+	+	+	+
Spearmint			+											+		n
Sumac	+		-	-			+	+	+	+		+	-	+	+	+
Sunflower	+	-						-			+	+			+	-
Thistle, blue	-		-							-		-		-		n
Thistle, star			-		+		+		-		+	+	+			+
Thyme	+								+					+	+	n
Titi	+						-		+	-	-	-	-	+	-	
Titi, spring	+	-	+	-				+	+	-	-	-	-			n
Trefoil	-											-		-	-	-
Tulip tree	+	-	-	-		+	+	+	+	+	-	+	-	+	+	

Table 1 (cont.)

	Color	Granulation	Levulose	Dextrose	Sucrose	Maltose	Higher Sugars	Undetermined	pH	Free Acidity	Lactone	Total Acidity	Lactone/Free Acid	Ash	Nitrogen	Diastase
Tupelo		-	+	-					-		+		+	-		
Alfalfa honeydew	+	+	-							+	-	+	-	+	+	n
Cedar honeydew	+	-	-	-		-	+	+	+	+		+	-	+		n
Hickory honeydew	+	-	-	-	+		+	+	+	+	-	+	-	+		n
Oak honeydew	+	-	-	-		+		+	+	+		+	-	+	+	n

Near average in all above characteristics except diastase, which differs as shown in parentheses: Wild buckwheat (+); clover, alsike; clover, sweet; clover, white; crotalaria (-); cucumber; eucalyptus; fireweed; heartsease (n); palmetto, cabbage; pentstemon (n); purple loosestrife (n); rosinweed (+); vetch; vetch hairy (-).

1/ "n" means insufficient data were available to allow valid comparison.

(Next month: - Identity of honey sugars.)

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A Survey of American Honeys

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3. Identity of Honey Sugars [1/]
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HONEY IS FIRST and foremost a carbohydrate material. Sugars make up 95-99.9 percent of the solids of honey and their identity has been studied for many years. In our survey of the composition of American honeys we have given a great deal of care and attention to the accurate and precise determination of the amounts of the various sugars in the honey samples.

New Methods for Sugar Analysis

In the past ten years or so a quiet revolution has taken place in the field of analytical chemistry. New materials, new methods and new instruments have brought about better, more rapid and more accurate analyses of many kinds. Analysis of honey sugars is no exception, and methods recently developed

1/ This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

After separation by irrigation, the different sugars in honey are revealed on the chromatographic paper by a color reagent. Results are discussed by J. W. White and Mary Subers. —Courtesy of USDA. Photo by M. C. Audsley.

Number three in a series of ten articles on different honeys of America.

for this purpose in our laboratory were used in our honey composition project. As a result of these improvements we now have new information helping clarify the complex picture of the sugars of honey. This new information is both qualitative - what kinds of sugars are present - and quantitative - measuring the amounts of the sugars.

Kinds of Sugars

Sugars may be grouped according to the size and complexity of their molecules. The groups of interest to us are three. These include the monosaccharides, or simple sugars. These are the individual "building blocks" of the more complex sugars, and are not further broken down without greatly changing their properties. Examples are dextrose and levulose, the predominating sugars in honey. The disaccharide sugars are also of interest to us; they are somewhat more complex than the simple monosaccharide sugars, being each made up of two such units. The kind of sugar and the type of linkage between them can differ, so that hundreds of disaccharides are possible. The best known disaccharides are sucrose (table sugar) and maltose. For our purposes, we consider all other more complex sugars together in one group, the higher sugars. These include trisaccharides, made up of three sugar units (such as melezitose) and even more complex sugars with four or more monosaccharide units. As the complexity of these saccharides increases they approach the structure of dextrins and starches.

Sugars Found in Honey

Honey was long thought to be mainly levulose and dextrose, with some sucrose and dextrins. These were considered to be poorly-defined complex sugars of high molecular weight.

With the advent of new methods for analyzing and separating sugars, workers in Europe, in this country and in Japan have found many sugars in honey and in some cases isolated and identified them by suitable physical and chemical methods.

The table shows the names of the sugars and gives some other information about them. Many of these have

Table 1. Sugars Identified in Honey

Name	Investigators
Monosaccharides	
Levulose	Long known to occur
Dextrose	
Disaccharides	
Sucrose	Long known to occur
Maltose	White and Hoban a/
Isomaltose	Watanabe and Aso b/; White and Hoban
Turanose	White and Hoban
Maltulose	White and Hoban
Nigerose	White and Hoban
Kojibiose	Watanabe and Aso
Higher Sugars	
Melezitose	Reported by Goldschmidt and Burkert c/ but not isolated or adequately identified.
Erlose	
Kestose	
Raffinose	
Dextrantriose	

a/ Arch. Biochem. Biophys. 80, 386 (1959).
b/ Nature 183, 1740 (1959)
c/ Z. Physiol. Chem. 300, 188 (1955).

As a check on the sugar analyses, Mary Subers places paper chromatograms in the cabinet for solvent irrigation.—Courtesy USDA. Photo by M. C. Audsley.

been considered very rare; some have never been found in a natural product before, though made in the laboratory.

Most of these sugars probably do not occur in nectar, but arise due to either enzymic action during the ripening of honey or by chemical action in the concentrated, somewhat acid sugar mixture we know as honey, during storage.

Sugars in Various Types of Honey

One of the questions we were concerned with in our analytical survey of American honeys was whether all honey contained the same sugars, especially the minor sugars, or if possibly certain types of honey would have different kinds of sugars. To check this, we examined all sugar solutions we analyzed from all samples by the process of paper chromatography. This is a way to separate the individual sugars from each other and to spread them out on paper so they could be counted and compared. In all of the honey samples we analyzed, the same patterns of sugars were found. There were often differences in the relative amounts of the various sugars, but all honeys appeared to have all of the sugars. This chromatographic check on the solutions we analyzed served also to assure us that our preliminary treatments of the samples were operating properly.

(Next month:- Effect of crop year on composition.)

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Number four in a series of ten articles on the different honeys of America.

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Analytical data are transferred to IBM cards by Judy Lorenson, prior to computation.—Photo by M. C. Audsley, USDA.

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A Survey of American Honeys

4. Effect of Crop Year on Composition [1/]

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IN THE COLLECTION of honey samples from over the United States for this project, honey was collected from the two crop years, 1956 and 1957. This was done because insufficient samples had been obtained from one year to fill our requirements, and

1/ This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

also because we hoped that information might be obtained that would throw some light on the amount of variation in honey attributable to the effect of the crop year. We realize that collection for only two years is quite insufficient to provide definitive information about this factor, but we were limited as to the number of samples we could handle, so were obliged to consider only the two years.

Average Composition for the Two Years

In the first article in this series the average analysis was given for all honey samples analyzed. Here we present the average analyses of all 1956 honey samples and of all 1957 honey samples. Table 1 shows the values. It can be seen that the average 1957 honey was somewhat lighter in color, slightly lower in granulation tendency, slightly higher in levulose, lower in undetermined material, and otherwise quite similar to the 1956 honey. These two averages are not made up of corresponding samples, however, and their

Table 1. Average Composition of Honey Samples for Two Crop Years

	1956	1957
No. of samples	182	297
Color	Light part of Extra Light Amber	Dark part of White
Granulation Tendency	1/2" layer of crystals	1/8-1/4" layer of crystals
Moisture (%)	17.0	17.3
Levulose (%)	37.92	38.36
Dextrose (%)	31.15	31.37
Sucrose (%)	1.32	1.31
Maltose (%)	7.44	7.22
Higher Sugars (%)	1.69	1.38
Undetermined (%)	3.4	2.9
pH	3.96	3.88
Free Acidity (meq./kg.)	22.16	21.95
Lactone (meq./kg.)	7.05	7.15
Total Acid (meq./kg.)	29.21	29.10
Lactone/Free Acid	0.336	0.334
Ash (%)	0.173	0.166
Nitrogen (%)	0.041	0.041

values depend on the sample response from producers for the two years.

Comparison of Legume Honey Averages

There are two other ways that our data can be studied to produce information on the general question of effect of crop year on composition of honey. One is by comparison of average values for the same floral types for the two years. The other is by comparison of samples from the same producer and from the same type and area for the two years.

There were seven important floral types and blends (110 samples) for which we had enough samples to allow averaging of values for each crop year. When this was done, it was seen that in practically all cases where there was a difference in the averages for the two years, it was no greater than the variation normally encountered between samples of that type of honey for one year. Statistical tests were applied and only in the case of granulation tendency were any significant differences found between the two years. Here the 1957 honey granulated less.

Comparison of Matching Individual Samples

For the final type of comparison of one year's honey with another, we had 22 samples, one from each year, from the same producer and location for 11 floral types. This kind of comparison should reflect actual differences in the "same" honey over the two years, since the samples are matching. This was not the case in the first two types of comparison.

The comparison of these samples is given in Table 2. Here a plus sign means that the 1957 sample was appreciably higher than the 1956 sample in that characteristic, a minus means the opposite, and no mark means that there was no difference. The last line of the table, "Total" gives the number of samples in which differences were found between 1956 and 1957 samples for that attribute. Here the size of the differences is about that amount that could be reliably detected using our

Table 2. Comparison of 1957 Samples with 1956 Samples, each from Same Producer, Location and Floral Type

	Color	Granulation	Moisture	Age	Levulose	Dextrose	Sucrose	Maltose	Higher Sugars	Undetermined	pH	Free Acid	Lactone	Total Acid	Lactone/Free Acid	Ash	Nitrogen
Alfalfa-sweet clover	-		+	+		-	-	+	+		-		-		-		-
Aster			+	-		-					-	+	+	+	+		+
Blend	-		-	-	+	+	-		+						+	+	
Chinquapin		+	+		+	+			-	-	-	+	+	+	+		+
Clover, white	-	-	+		-	-		+			-					-	
Coralvine			+			-											+
Cotton					-		-									+	+
Gallberry	+		+	-	-	+		-	-	-	-	+	+	+	+	+	
Privet	-					+	+	+		-	-	-	-	-		-	
Raspberry				-	-	-	-	-	+	+	+	+	-	+	-	+	+
Vetch		-	-		-	-	+	+	+							+	
TOTAL	5	3	8	5	7	10	6	6	6	4	7	5	6	5	6	7	6

analytical methods. Many of them have little actual effect on properties and uses of the honey. Thus, dextrose content is the most variable property in these samples, with 10 of 11 samples showing differences from year to year. These differences were generally small however, since only three samples had appreciable differences in granulating tendency. As might be expected, moisture content showed a high degree of variation. The 1957 samples were generally higher in moisture than those from 1956. The variability of other factors may be seen in the table.

In presenting and discussing these results, we do not mean to suggest that there is at this late date any practical interest in honey from the 1956 and 1957 crops as such. Rather these data and discussions are meant to give a general idea of how much variation can be expected from this source.

The complete individual analytical values and a more complete discussion of all the factors here described is planned to be published as a U.S. Department of Agriculture Technical Bulletin.

Next month: - Effect of area of production on composition.

The cards bearing the analytical results are machine sorted by Dr. White during the analysis of the data.—Photo by M. C. Audsley, USDA.

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A Survey of American Honeys

5. Effect of Area of Production on Composition 1/

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Number five in a series of ten articles on different honeys of America.

IN THE FIRST FOUR articles in this series we have discussed the need for new information about the composition of honey and presented a new table of average composition of honey. It has been shown that the same sugars are always found in honey, at least among the monosaccharides and disaccharides, no matter what type it is or where it is produced. It has also been noted that from one year to another, some variation, particularly in granulating tendency, dextrose and moisture content, may be expected.

Another of the many factors that might influence the composition of honey is the area of production. How much difference can we expect between honey of the same floral type grown in different locations, either relatively close together or widely separated? In this instance a number of factors may have an influence, with the final honey composition reflecting the interplay of differences in soils, rainfall, sunshine and other weather factors, different varieties of plants, different farming practices, different minor or competing floral sources, and so on.

Several comparisons of samples may be made to get some information on this point. With our honey samples from 176 floral types and blends of known composition, from 47 of the 50 states, we can make several types of comparisons to clarify these effects.

Valley and High-altitude Alfalfa Honey Compared

It is well known that Imperial Valley alfalfa honey is different from intermountain alfalfa honey in color and flavor, being darker and of more pronounced flavor. Beyond that, little is known of other differences that might exist between these two types of alfalfa honey. In Table 1 we find such a comparison. The four valley alfalfa samples which were averaged were from Southern California; the eight intermountain samples originated in Wyoming, Utah, Montana, Idaho and Colorado.

In addition to the flavor and color differences already known, it appears that the valley alfalfa is slightly lower in levulose and slightly higher in dextrose. It also seems to be more prone to granulate. The ash content of the valley alfalfa honey is over twice as high as the intermountain honey. It shows considerably greater content of lactone and acid, but their ratio does not differ from that of the high-altitude alfalfa honey, and the pH value is the same. Otherwise the two types of honey are similar.

When these figures were examined with the aid of statistical procedures, it

1/ This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

was found that none of the differences in Table 1 (except granulating tendency) are statistically significant. Thus we found no real difference in composition between alfalfa honey produced in these two areas.

Table 1. Average Composition of Alfalfa Honey from Diferent Areas

	Intermountain	Imperial Valley
Color	Light half Extra White	Dark half Extra Light Amber
Granulating tendency	¼-½" layer	Complete
Moisture (%)	16.4	15.8
Age at anal. (mo.)	8	16
Levulose (%)	39.55	37.88
Dextrose (%)	33.28	34.11
Sucrose (%)	2.42	2.88
Maltose (%)	5.85	5.85
Higher sugars (%)	0.80	0.83
Unanalyzed (%)	1.7	2.6
pH	3.83	3.84
Free Acid (meq./kg.)	15.18	22.55
Lactone (meq./kg.)	6.42	9.98
Total Acidity (meq./kg.)	21.60	32.53
Lactone-Free Acid Ratio	0.423	0.442
Ash (%)	0.059	0.158
Nitrogen (%)	0.026	0.032

The first step in the analysis of honey sugars is shown by Irene Kushnir, passing them through a charcoal column.—USDA photo by M. C. Audsley.

Cotton Honey from Three States

Cotton honey is characteristically rapidly-granulating and hence differs from many other honey types. In Table 2 is shown a comparison of the averages of two samples from Texas, four from Arizona, and three from California. These averages are remarkably similar. No striking differences in composition are apparent. The California average is slightly higher in sucrose, definitely of lower pH (higher active acidity), somewhat higher in lactone/acid ratio, and somewhat lower in ash. The Arizona average is definitely lower in nitrogen content, being but half of the other two. None of these differences should have any perceptible effect on the uses of the honey.

Eastern and Western Orange Honey

A third comparison of this sort is between California orange honey (three samples) and Florida orange (orange-

Table 2. Average Composition of Cotton Honey from Different Areas

Color	Texas Dark half of White	Arizona Dark half of White	California Light half of White
Granulating tendency	Complete soft	Complete soft	Complete soft
Moisture (%)	15.6	16.3	16.1
Age at analysis (mo.)	9	7	15
Levulose (%)	39.42	39.08	39.77
Dextrose (%)	37.21	37.35	36.18
Sucrose (%)	0.80	1.17	1.52
Maltose (%)	5.02	4.55	4.85
Higher Sugars (%)	0.42	0.57	0.46
Undetermined	1.5	1.2	0.9
pH	4.42	4.39	4.12
Free acidity (meq./kg.)	26.23	23.07	25.29
Lactone (meq./kg.)	5.08	3.85	7.09
Total acidity (meq./kg.)	31.31	26.92	32.38
Lactone/Free acid	0.194	0.166	0.280
Ash (%)	0.339	0.406	0.258
Nitrogen (%)	0.047	0.024	0.047

Table 3. Average Composition of Orange Honey from Two Areas

Color	California Light half of White	Florida Dark half of White
Granulating tendency	½" layer	¼ of depth
Moisture (%)	16.7	16.6
Levulose (%)	39.26	38.70
Dextrose (%)	31.83	31.82
Sucrose (%)	1.87	2.00
Maltose (%)	6.50	7.70
Higher sugars (%)	1.33	1.51
Undetermined (%)	2.5	1.3
pH	3.67	3.89
Free acidity (meq./kg.)	24.23	21.27
Lactone (meq./kg.)	13.12	7.28
Total Acidity (meq./kg.)	37.35	28.55
Lactone/Free acid	0.540	0.352
Ash (%)	0.082	0.067
Nitrogen (%)	0.030	0.009

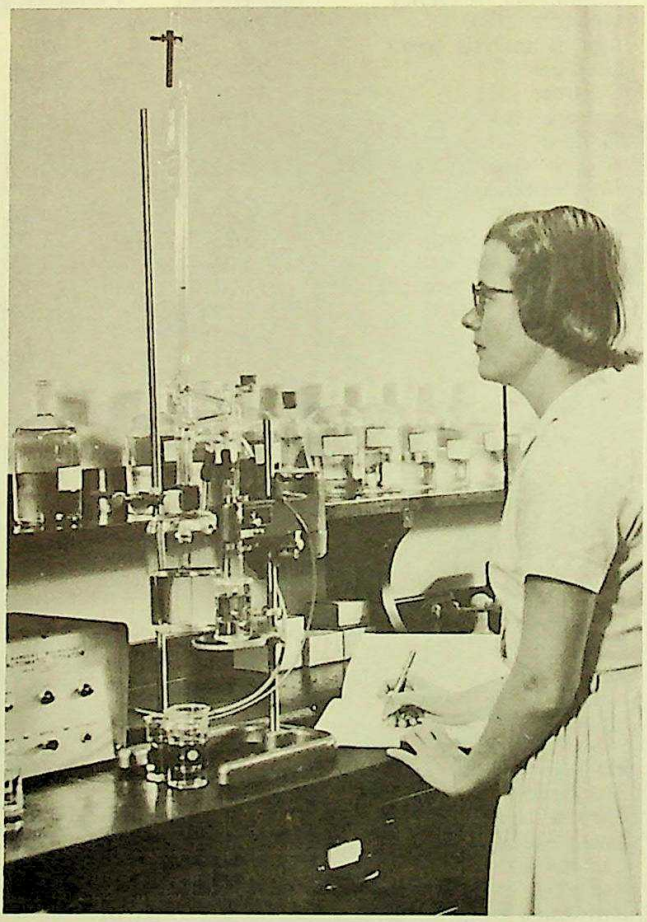
grapefruit, three samples) honey. The data are given in Table 3. These values are quite similar, with the California honey showing more acid, lactone and a higher lactone/acid ratio. The Florida average is unusually low in nitrogen. These last three differences are statistically significant. Otherwise, from an analytical point of view, there is very little or no difference between this type of honey, from Florida or California.

Comparison of Pairs of Samples of Honey

We may also compare individual samples of the same floral type from different areas. If this is done, considerable differences show up, reflecting the contributions of some of the factors mentioned earlier. In such a comparison of five pairs of samples, three had similar analyses, while two pairs showed considerable differences, particularly in dextrose and levulose and acidity.

In order, then, to find any general effects of location of production on the composition of honey, such comparisons should be made on considerable numbers of samples from each area, rather than single samples. When this is done with a limited number of samples we have seen that highland and valley alfalfa are quite similar in composition though differing in color and flavor; cotton honey from three states is quite similar; and orange honey from California is very similar in composition to that from Florida.

(Next month:-Relation of granulating tendency to composition.)



Many of the sugar analyses were done with the automatic titrator; Mary Subers records a value in the notebook.—USDA photo by M. C. Audsley.

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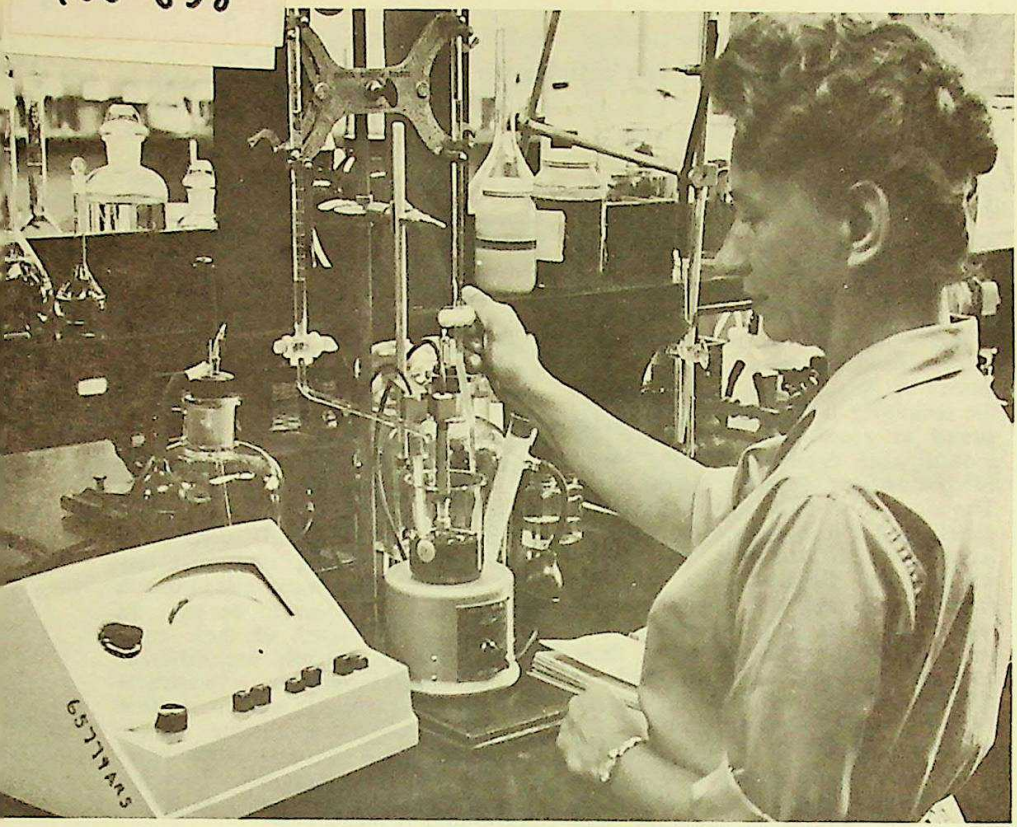

A new procedure for determination of free and total acidity and lactone in honey is run by Irene Kushnir.—Photo by M. C. Audsley, courtesy U.S.D.A.

A Survey of American Honeys

6. Relation of Granulating Tendency to Composition [1/]

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Agricultural Research Service, United States Department of Agriculture
Philadelphia 18, Pennsylvania

1/This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

Number six in a
series of ten articles on
different honeys of America.

IN THE ANALYTICAL survey of the composition and properties of American honeys which we have carried out over the past three years, we applied a simple test of granulating tendency to the 504 samples that were analyzed.

It was necessary to heat the samples before chemical analysis, either to pasteurize or liquefy them. After analysis the remaining liquid honey sample was stored at room temperature for six months, then examined for the extent of granulation that had taken place. The amount of granulation, from completely liquid to complete hard granulation, was divided into ten classes which were assigned code numbers from 0 to 9. When the results of the analyses of the honey samples were averaged by the IBM computer, these code numbers were also averaged. It is debatable whether such an average number would accurately reflect the granulation tendency of a mixture of the samples being averaged, but since the numbers represent an increasing degree of granulation tendency and this factor depends on composition, much information was gained by this approach.

Honeys Grouped by Granulation Tendency

We collected together all the IBM cards for samples showing the same granulating tendency and the average composition of each group of samples was then computed. In Table 1 we can see the results of this calculation. The most striking features are the increase in dextrose content as granulation tendency increases, and the relative constancy of the levulose values. In some of the remaining columns, a regular trend may be present, and in others there does not appear to be any. In order to decide which of these composition factors actually are different in the different groups, a statistical analysis was made. It was found that all of the following factors change significantly[2/] as the granulation tendency of the honey increases. They are arranged in descending order as far as significance is concerned:

Factor	Change as Granulation Tendency Increases
Dextrose	Increases
Maltose	Decreases
Moisture	Decreases
Higher Sugars	Decreases
Undetermined	Decreases
Sucrose	Increases

Color was found to decrease, but in a less significant manner. None of the other factors varied in any significant manner with granulating tendency.

From the point of view of composition, the most important factor involved in stability of honey on storage is dextrose content. This is logical but not new, since dextrose is the material that granulates out. Non-granulating honeys are higher in "maltose" than rapidly-granulating honeys. This is also logical since the maltose arises from the dextrose in the honey. The moisture content also appears to play a role. A most interesting point arising from this table is that levulose content is not significantly different in any of these groups of honey samples.

Indices to Predict Granulating Tendency

In the past the levulose-dextrose ratio (L/D) has been widely used to re-

2/ Exceeding the F value at the 1 percent probability level by analysis of variance for regression.

late the granulating tendency of a honey to its composition. Several other indices for granulation have been proposed, but none has been shown to be especially useful. The purpose of a granulation index is to allow us to predict the granulation tendency of a honey from its composition.

We have calculated several of these indices from the data in Table 1. Then we determined statistically which of five indices had the most highly significant relationship to the granulating tendency. The one that appears most useful is the ratio of dextrose to water, which was proposed by G. H. Austin of the Canadian Department of Agriculture several years ago. Although he proposed calculating all results to a common moisture content before comparison, we find that this is not desirable since it decreases the sensitivity of the index. Another index proposed by workers at the National Bureau of Standards many years ago [(dextrose-water)/levulose] is as closely related to granulation as Austin's index, but is somewhat more difficult to determine and calculate.

The old levulose/dextrose ratio is much less useful than these. This is expected since the levulose content of the "average honeys" in Table 1 does not vary significantly with granulation tendency.

Relation of Dextrose/Water Ratio and Granulation

The numerical values for the D/W ratio for each class of granulating tendency are given below.

Granulating Tendency	D/W
None	1.58
Few scattered crystals	1.76
1/16"-⅛" layer of crystals	1.79
Few clumps of crystals	1.86
¼"-½" layer of crystals	1.83
¼ of depth granulated	1.99
½ of depth granulated	1.98
¾ of depth granulated	2.06
Complete, soft granulation	2.16
Complete, hard granulation	2.24

These calculations are based on the average compositions of large groups of honey samples, shown in Table 1. They do not give the properties of any actual existing honey samples. It is quite possible that by averaging in this way we have smoothed out individual variations that might be large enough to rob the proposed index of any practical value, that is, of prediction of granulating behavior of individual samples.

Prediction of Granulation Tendency

To find out if such was the case, a statistical examination was made of the relationship of granulation tendency of all samples, individually, with three of the indices, D/W, $\frac{D \cdot W}{L}$, and L/D. This was done on the IBM computer and the results agreed with those we found for the averages, in that the old L/D ratio was much less useful than either of the other two, which were of approximately equal value. The prediction is of course not infallible, but should be useful. It seems reasonable to say that D/W values of 1.70 and lower are associated with non-granulating honey and that values of 2.10 or higher predict rapid granulation to a solid. Intermediate values seem to mean intermediate degrees of granulation tendency.

Caution in Use of D/W Ratio

It must be noted that the use of the D/W ratio is valid only if the dextrose content of a honey is determined by a method giving true dextrose values. Older methods of sugar analysis, in which other sugars are "lumped together" with dextrose will give falsely high dextrose values and therefore high values for the D/W ratio. Such methods include any in which there is no preliminary separation of sugars into classes. This includes the classic polarimetric methods and also hypoiodite methods if used without preliminary separation of sugars.

(Next month--Relation of color to Composition)

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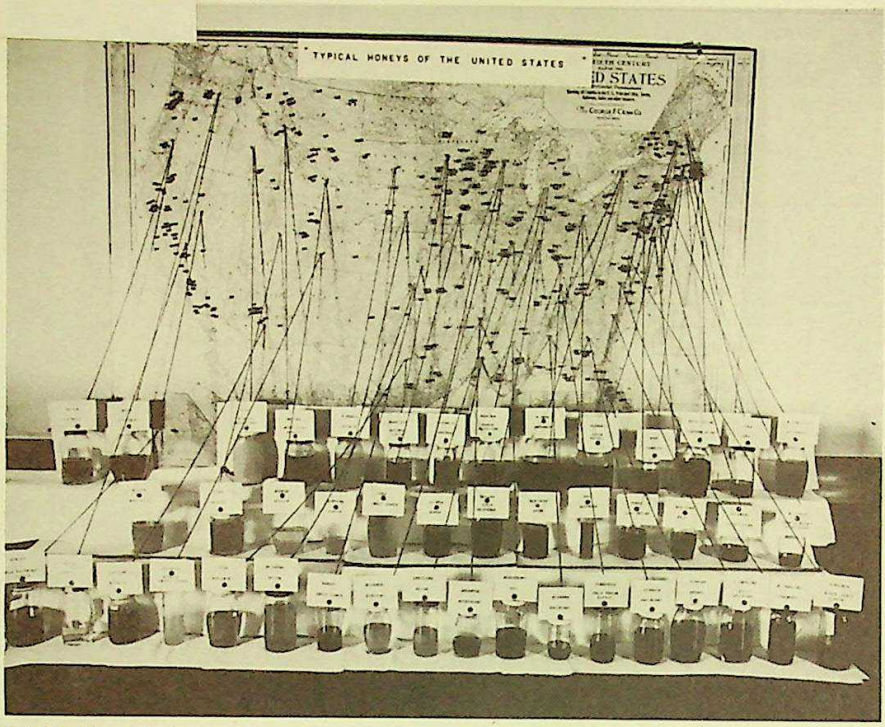

Exhibit shows typical honey samples from 45 states. Each dot on the map represents one honey sample analyzed.—USDA Photo by M. C. Audsley.

A Survey of American Honeys

Number seven in a series of ten articles on the different honeys of America.

7. Relation of Color to Composition [1/]

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1/ This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

COLOR OF HONEY is its most quickly noted characteristic, and it has long been used to form quick opinions of its other characteristics. Many believe that the strength (or desirability?) of flavor can be inferred from its color. It is known that some analytical characteristics of honey vary with its color. Schuette and his colleagues at Wisconsin found that the darker honeys are richer in ash, potassium, sodium, magnesium, iron, copper, manganese, chlorine and sulfur. They also found that enzyme contents of dark honeys are higher than of light honeys.

Honeys Grouped According to Color

In our recently concluded analytical survey of American honey, we grouped all honey samples into 13 color groups, representing the light and dark halves of the seven USDA color classes for honey. As was done for the granulation data, described in the preceding article in this series, code numbers from 0 to 12 were assigned to the groups, ranging from "0" for the light part of water white to "12" for dark. All analyses were then grouped and averaged, to give the average analysis for all honeys falling in each of the color groups. These averages were examined for trends and statistical analysis was used to find out if the trends that appeared to be present were actually significant.

Significant Differences Between Light and Dark Honeys

When this was done, many of the compositional factors were found to change in a regular way when darker honeys were studied. As we progress from light to darker groups of honey samples, the following factors decrease, i.e. they are higher in light than in dark honey (all are listed in order of decreasing significance[2/]):

Sucrose
Lactone/Acid Ratio
Dextrose
Active Acidity
Levulose
Granulating Tendency

These composition factors were found to be higher in darker honeys than in lighter:

Total Acid
Free Acid
Nitrogen
Ash
Undetermined Material
Maltose

This is further substantiation of the fact that darker honeys are richer in minerals (ash) than lighter ones. They are also much higher in total acidity, but are lower in dextrose and levulose and have a lessened tendency to granulate.

Color of Honey Over the United States

Recently an exhibit was made up showing typical honey samples arranged with a map of the United States. It could be seen that honey of the East and South was darker and that as one went westward, honey lightened considerably. This is not a new observation, but it is of interest that when all of our honey samples were classified by state of origin and further by area of the United States, this was again shown. This may be seen by the following values. Here the code numbers for color were averaged. Whether this procedure would give the same value for color as would be obtained by blending the samples is debatable, but we feel that it gives a good approximation.

Thus, honey from the East and South in general is darker than the national average while that from the north central and intermountain area is lighter.

(Next month: - Effect of storage on honey sugars.)

Area	No. of Samples	Average Color
North Atlantic States	82	Light half Ex. Light Amber
East North Central	47	Light half White
West North Central	63	Light half White
South Atlantic	86	Dark half Ex. Light Amber
South Central	68	Light half Ex. Light Amber
Intermountain West	52	Light half Extra White
West	104	Dark half White
All samples	502	Dark half White

2/ All factors shown gave F values in the analysis of variance for regression exceeding the critical value for the 1% probability level.

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A Survey of American Honeys

8. Effect of Storage on Honey Sugars [1/]

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IT IS WELL KNOWN that honey will darken when it is stored for long periods of time. Milum at Illinois studied this some years ago and also included the effects of some processing variables on color development in storage. In the European literature on honey it was recorded by Auerbach and Bodlander that as honey was stored, its levulose/dextrose ratio increased. De Boer did not confirm this and said that in his experiments no changes took place in the sugars. He did note that other changes that occurred in storage of honey were similar to those that were brought about by heating of honey. By this he meant darkening, decrease in diastase and increase in hydroxymethylfurfural (HMF, a degradation product of sugars).

During our laboratory work on the complete analysis of 504 samples of American honeys from over the entire country, we had the opportunity to do some work on the effects of storage on the composition of honey.

By using cold storage at -4°F. for portions of honey samples when they were received, they could be held without further changes taking place in them. Then, at a suitable time, these samples and corresponding samples that had been stored at laboratory room temperature (73-82°F), were analyzed. Sugars, acids and diastase were determined, since these were the materials that might be expected to change in storage.

Changes in Sugars in Storage

Five unheated honey samples were each divided into three parts when received from their producers. As noted above, part was placed in cold storage and part stored at room temperature. The third part was heated at 130°F. for 30 minutes, cooled and stored at room temperature.

The samples were analyzed after 20-23 months storage. The differences among the sugars in the two room-temperature samples and the cold-storage sample were definite, but it was not clear whether any real differences were present between the heated and raw room-temperature-stored samples. The results were analyzed statistically[2/]. When raw or mildly heated (130°F., 30 min.) honey was stored for one and one-half to two years at a temperature ranging between 73° and 82°F., the following changes took place:

1. A decrease of the free dextrose averaging 13% of that present and a decrease in free levulose averaging 5.5%; an average of 18.5% of the free monosaccharide content of the honey was lost.
2. A large increase in "maltose" or reducing disaccharide content, averaging 68% of that originally present.
3. A slight though real increase in sucrose content.

1/ This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

2/ All F values exceeded the critical value at the 1% probability level.

4. A small (13%) increase in higher sugars present.

5. An increase (averaging 22%) in the unanalysed material.

These changes are in the direction of increased complexity of sugars. They are probably brought about by two mechanisms - chemical and enzymatic. A high sugar concentration and a considerable acidity, both of which are present in honey, are known to promote a slow combination of simple sugars to more complex types of sugars. It is also thought that the enzymes in honey bring about slow increases in the amounts of more complex sugars.

Why Granulated Honey Softens or Liquefys in Time

The decrease in dextrose content on storage is about twice that for the levulose. It is large enough to have a real effect on the granulation tendency of honey.

It was proposed in an earlier article in this series that granulating tendency of honey can be predicted from the dextrose/water ratio: values of 1.70 or less are associated with non-granulating honey, while samples showing a ratio of 2.10 or more will granulate complete and hard. Since one and one-half to two years storage at ordinary temperatures can decrease dextrose content by 13% this will decrease the D/W ratio.

Portions of most samples were stored in the freezer at 20 degrees below zero, centigrade. Irene Kushnir selects samples for analysis in a storage study.—USDA photo by M. C. Audsley.

In the samples we analyzed, storage caused the ratio to decrease by an average of 0.25. Thus a honey of a moderate granulating tendency (D/W = 1.90) would in time become a non-granulating type (D/W = 1.65). Many beekeepers are familiar with the slow "melting" or liquefaction that takes place when a jar of granulated honey is stored for an extended time. This is brought about by the decrease in free dextrose, due to the causes noted above. This action brings the dextrose content in the liquid part of the honey below the amount needed for saturation. This then requires that enough of the granulated, solid dextrose dissolve to bring the concentration in the liquid part back to the saturation level.

This probably is one of the causes of partial liquefaction or excessive softening in finely granulated (Dyce-processed) honey spread when stored too long at room temperature before use. The most obvious way to prevent this is by reducing the storage temperature sufficiently to retard the loss of free dextrose. Ordinary refrigeration will be sufficient for this purpose. It will retard both the chemical and enzymatic reactions involved.

(Next month: - Effect of storage on diastase content.)

Acidity of Honey Increases During Storage

A group of 10 honey samples were stored without heating, both in cold storage (-4°F.) and at room temperature. These were then analyzed for acidity after two years of such storage. None of the samples showed any visible signs of fermentation. Statistical analysis of the results showed that significant[3/] increases in free acidity, lactone and total acidity had taken place in the samples stored at room temperature. We have found a significant relationship between the rate of increase of acidity and enzyme activity in these honeys. This is further evidence that honey contains an enzyme that slowly produces acidity in honey.

3/ Exceeding the critical value at the 1% probability level.

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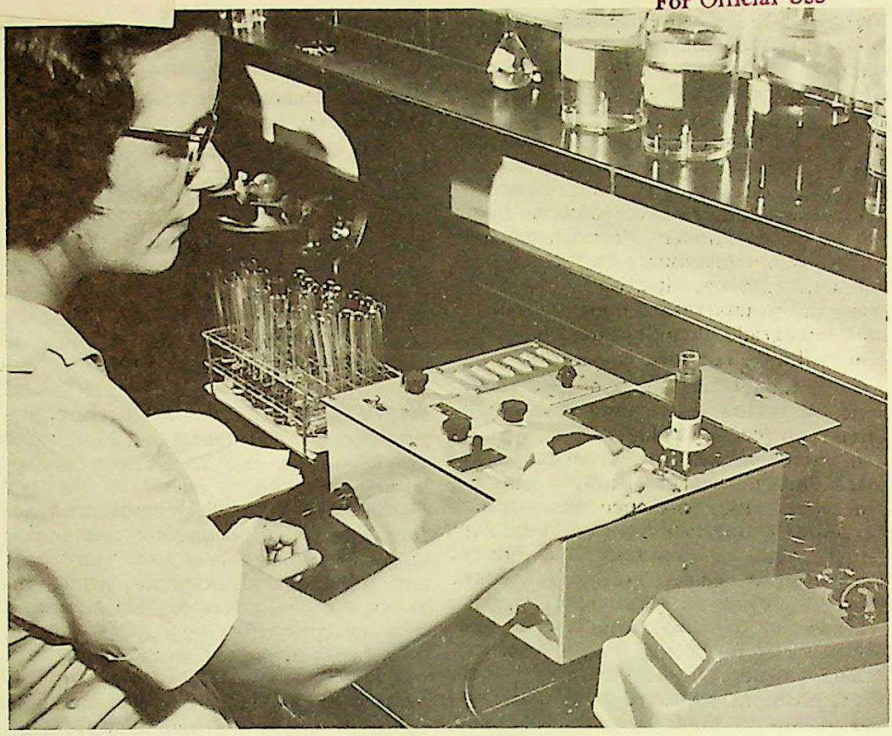

Using the new Schade method, Mary Subers determines the diastase number of honey with the photoelectric photometer. – A USDA photo.

A Survey of American Honeys

Number nine in a series of ten articles on the different honeys of America.

9. Effect of Storage on Diastase Content 1/

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1/ This is one in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

DIASTASE (or more properly, amylase) is an enzyme that "digests" starch. It has long been known to occur in honey. Its function in the ripening of honey is not clear, nor is it known with certainty if it is introduced by the bee or arises from a plant source (nectar, pollen, yeasts, etc.). Conceivably, diastase in honey could arise from all those mentioned. Periodic interest is shown in this country in the diastase content of honey; it arises when European importers refuse honey shipments or downgrade them because they find low values of diastase in samples.

It is thought in some European countries that honey loses much of its nutritive or protective value when it is heated. Since the enzyme is destroyed or weakened by heat, and is fairly easy to measure, the presence of certain amounts of diastase have been used for many years as assurance that honey has not been heated excessively. There have been some differences of opinion on whether a honey may have a low diastase value, but still be an unheated honey. There is no doubt that some types of honey produced in this country are so low in diastase as to not meet European requirements, even though they had never been heated. This, and other evidence that showed variable effects of heating on diastase content, have led to modification of import reglations in West Germany, though at this time the new rules are not known.

In general it has been held that heating is the only factor that would weaken diastase in honey. Information in the Dutch and German scientific literature indicated that some honeys lose some diastase in storage, but no definitive work was reported. In this country, Schade, Marsh and Eckert 2/ at Davis, California, recently developed a new method for diastase determination that appears to have won favor in Germany. We have used it for our studies on the composition of American honeys.

As was described in the preceding article in this series, some of the honey samples which we received from producers for this project were divided. Part was stored at -4°F. which minimized chemical and enzymic changes. After a suitable interval, these samples and their corresponding samples stored at room temperature (73°-82°F.) were analyzed for diastase activity.

Diastase Decreases in Storage Without Heating

None of these samples had ever been heated. Twenty pairs of samples stored at the two temperatures were analyzed. The time of such storage varied from 4 to 21 months. All sub-samples stored at room temperature showed much lower diasase values than the corresponding part of the sample stored at -4°F. They did not all show the same rate of loss. The average diastase value of the cold storage samples was 22.0, while that of the portions stored at room temperature for an average of 13 months was 13.4. This is a 38.9% loss of diastase, corresponding nearly to 3% per month. Many of the samples with acceptable (to European importers) diastase values had values after storage of one to one and one-half years that would not be acceptable. Only samples with exceptionally high values at the start had values that would be considered good at the end of the storage period. Furthermore, it was found that the rate of loss for high diastase samples was significantly greater than was the rate for moderate or low-diastase honeys.

Another way to express our results is that in ordinary storage at room temperature without heating, diastase in honey has a half-life of 17 months. This means that in 17 months a sample will lose half of its diastase. In 17 more months, half of the remaining diastase would be lost, and so on.

Further Work Planned

We are planning to look further into the stability of diastase and other enzymes in honey during different temperatures of storage. It is not uncommon in processing and storage for honey to be exposed to temperatures much greater than those used here. Temperatures averaging 85° or 90°F. for a few weeks or months might have several times the effect of 70°-75° temperatures. None of this enters the realm of the effect of heat processing of honey, which has been the aspect of this problem previously studied.

There is one additional bit of information in the literature on the effect of ordinary storage of honey on its dias-

2/ Schade, J., Marsh, G. E., and Eckert, J. E. Food Research 23, 446 (1958).

tase content. In the work of Schade, Marsh and Eckert referred to above [2/], they published data on seven honey samples stored at 20°C. (68°F.) for 13 to 15 months. They stated that the diastase activity had "decreased slightly but not significantly in most cases". Using their data, we analyzed them statistically and found that the changes were highly significant [3/]. Their data showed an average decrease for the seven samples on which they gave data of 10.1% in diastase number, or 0.72% per month. This rate of loss is real, but does not present a serious practical problem.

3/ Exceeding the critical value at the 1% probability level.

Factors Affecting Diastase Loss Rate

We attempted to find if any significant relationship existed between the rate of loss of diastase in our storage experiments and the composition of the honey samples. Among the 20 samples the average rate was 2.95% per month, but the lowest rate was 1.41% and the highest 4.76%. No significant relation was found with moisture, total acidity, hydrogen ion concentration (an expression of active acidity or pH) or ash content. Rate of loss was found to be significantly [3/] higher in the samples stored shorter times (4-8 months).

(Next month: - Summary and conclusion.)

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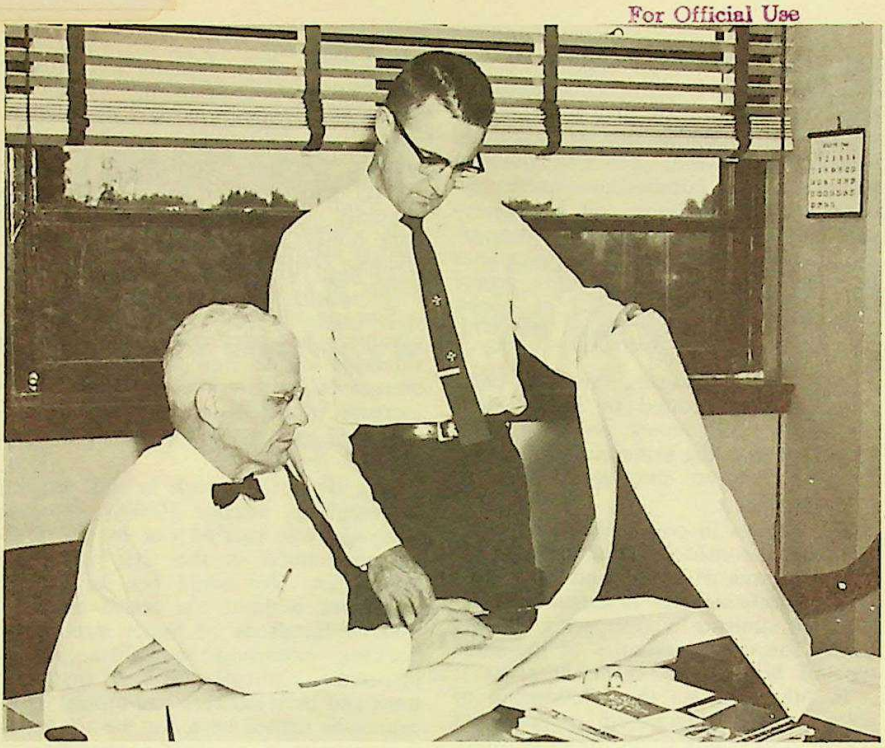

Results of honey analyses as printed by the IBM computer are discussed by Dr. J. W. White, Jr. and Dr. R. E. Lothrop, Assistant Director of the Eastern Utilization Research and Development Division. Dr. Lothrop is well known to beekeepers and processors, having devoted about ten years to honey research. – USDA Photo by M. C. Audsley.

A Survey of American Honeys

10. Summary[1/]

This is the last of a series of ten articles on the different honeys of America.

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1/ Last in a series of articles describing a large-scale study of the composition of honeys from over the United States. Complete data interpretation and conclusions will appear in a forthcoming Department of Agriculture publication.

IN THE PREVIOUS articles in this series, we have attempted to describe briefly the high-lights of our analytical survey of the composition of American honeys. We have presented average values for the composition of honey, based on 490 analyses, and for honeydew based on 14 analyses. A listing of 74 types of honey and 4 honeydews has been included which shows generally how the various kinds of honey compare with average values and with one another.

The kinds of sugars, rare and common, that are found in honey were discussed. All honey samples were found to have the same sugars present, but the relative amounts did differ considerably.

Differences in composition of honey have been considered that can be ascribed to area of production. Probably the only reliable way to assess this factor is by statistically comparing average values for several samples of the same type of honey from different areas.

In other articles the relationship of color and of granulating tendency of honey to its composition were discussed. It was shown that the granulating tendency of honey can be predicted from its dextrose and water content. A D/W ratio of 1.70 or less generally means a non-granulating honey, while a value of 2.10 or more predicts a relatively rapid complete granulation. Values between these imply partial granulation.

In comparing dark honeys with light honeys, we have confirmed that the former show higher ash and nitrogen contents. We have also shown that the dark honeys are lower in dextrose and levulose content, granulate less, and are higher in acids.

Storage of honey at ordinary temperatures has been seen to cause considerable loss in free simple sugars, increases in more complex sugars, some increase in acids and rather considerable (3% per month) losses in diastase content.

The laboratory work in this project, representing nearly 10,000 separate analyses, was carried out by the individuals named in the first article in this series. We could not have done this work without the active cooperation of hundreds of honey producers, packers, extension specialists, apiary inspectors, national and state organizations and their officers and others. They cannot be named here, but we are greatly appreciative of their cooperation.

All of the individual analytical results, complete descriptions of all samples, and names of those cooperating appear in the final technical bulletin to be published by the Department of

Data obtained by analysis of honey was processed on the computer by Charles Hopkins of the Computing Laboratory of the Agricultural Research Service at Beltsville.—USDA Photo.

Agriculture. This will also contain descriptions of the analytical methods used, a review of the literature and show the statistical evaluations of the data.

In addition to the principal tables of data, averages are included for all floral types and blends in which more than one representative was present. Average values of all honey samples as classified by plant family is given, and a table showing the average composition of honey from each of the 47 states having samples, as well as a map showing sample distribution.

No mention has been made in these articles of the flavor of honey. This does not mean that it is not considered important, but simply that it is difficult to measure and practically impossible to describe. It is, of course, probably the most important single attribute of honey, and possibly the one that is least understood chemically. More attention should be given to flavor and its maintenance in honey, especially protection against processing factors within our control.